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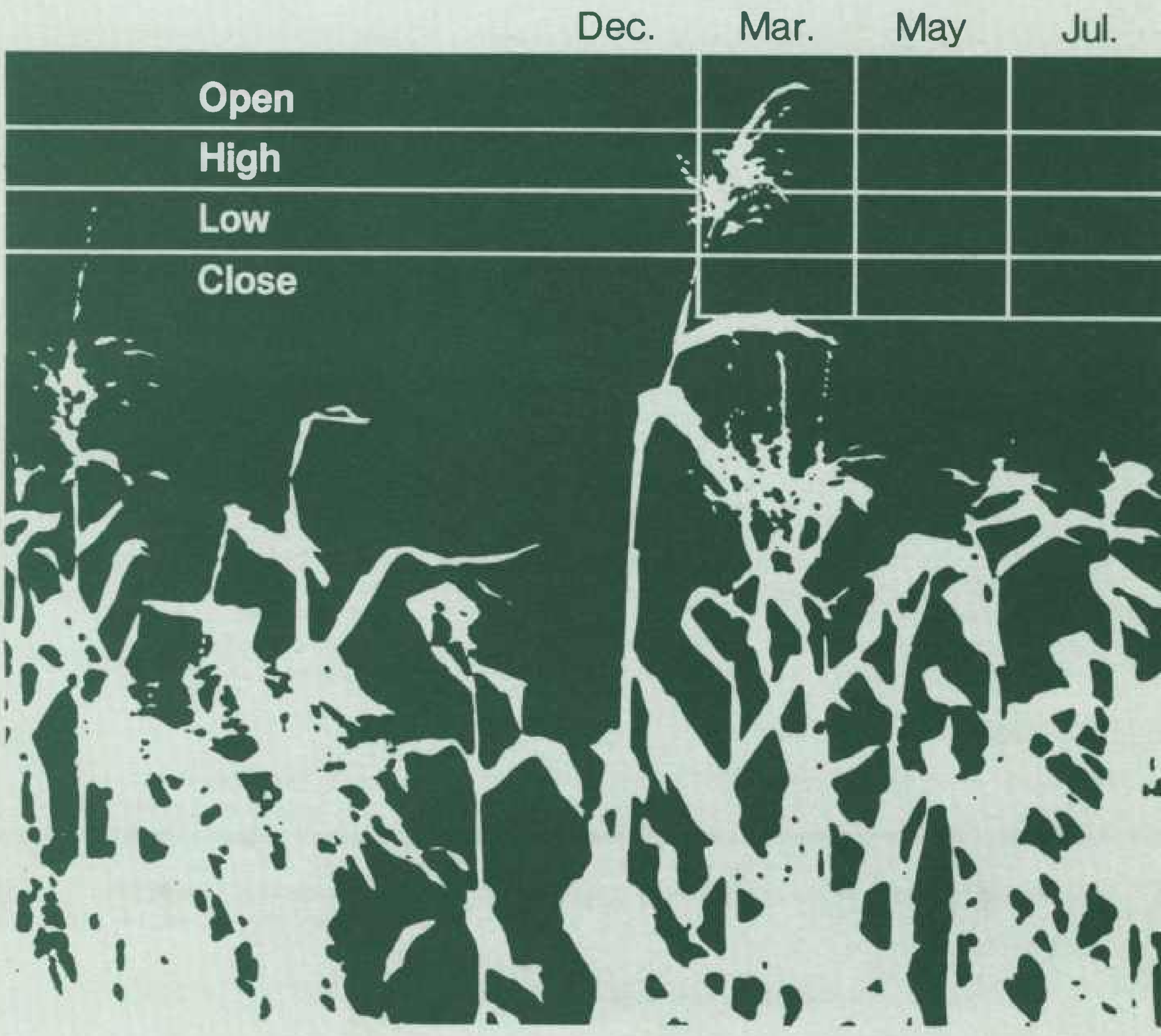
Optimal Futures Positions for Corn and Soybean Growers Facing Price and Yield Risk

Dwight Grant



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OPTIMAL FUTURES POSITIONS FOR CORN AND SOYBEAN GROWERS FACING PRICE AND YIELD RISK. By Dwight Grant, Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1751.

ABSTRACT

Hedging by selling futures or cash forward contracts before harvest reduces farmers' revenue risks by helping to assure the price to be received for a crop before it is ready to be sold. Hedging at planting time with contracts equal to 50 to 80 percent of expected output would minimize revenue risks for most corn and soybean growers. Still, these risk-minimizing hedges would eliminate less than 50 percent of farmers' revenue risks, on average, and would be costly. Farmers' best hedging positions may cover less than 30 to 50 percent of expected output because of the cost of selling futures and because the last 20 percentage points of a hedge reduces very little risk. This report presents a model of futures trading for producers with random yields and applies the model to corn and soybeans using 1961-83 data for counties in Iowa, Nebraska, and North Carolina; for selected States; and for the United States. The estimated risk-minimizing hedges provide farmers starting points for deciding how much of their expected crop to sell before harvest.

KEYWORDS: Risk, futures trading, hedging, pricing, corn, soybeans

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SUMMARY

Selling futures or cash forward contracts (hedging) before harvest reduces farmers' revenue risks by helping to assure the price to be received for a crop before it is ready to be sold. Selling futures or making cash forward sales equal to 50 to 80 percent of expected output would minimize revenue risks for most corn and soybean producers. These risk-minimizing hedges would eliminate less than 50 percent of farmers' revenue risks over the growing season, on average. Farmers should sell less forward if they expect prices to rise or more if they expect prices to fall. Farmers' best hedging positions may average less than 30 to 50 percent of expected production, because selling futures may be costly and a 20-percentage point reduction in the hedge has relatively little effect on the amount of risk protection obtained.

This report presents an analytical model of futures trading for crop producers with random yields. The model estimates the size of the futures positions that minimize revenue risk and the risk-reducing effectiveness of these futures positions. The model is applied to corn and soybeans using 1961-83 data for counties in Iowa, Nebraska, and North Carolina; selected States; and the United States.

Minimum-risk hedge ratios are the proportion of expected output that should be sold forward to minimize revenue risk. The effectiveness of a hedge is measured as the fraction of the revenue variance eliminated by the hedge. If revenue risk were due solely to price variability, farmers could minimize their revenue risk by selling forward about one bushel for each bushel of expected production. This ratio is generally less than 1 for farmers in areas where yields vary. Selected averages of the minimum-risk hedge ratios and measures of hedge effectiveness are as shown in the table below.

The hedge ratios calculated at the aggregate level (national, State, or county) apply on average at the farm level, but estimates of hedge effectiveness at the aggregate level overestimate hedge effectiveness at the farm level.

Losses from selling futures at planting time and buying back at harvest averaged 3.36 percent of the expected harvest price for corn and 5.29 percent for soybeans during 1961-83. If such losses were expected in the future, the best hedges would be much less than those shown in the table.

Summary of minimum-risk hedge ratios and hedge effectiveness

Area	Corn		Soybeans	
	Hedge ratio 1/	Hedge effectiveness 2/	Hedge ratio 1/	Hedge effectiveness 2/
Iowa counties	0.73	0.57	0.73	0.65
Nebraska counties	.68	.42	.67	.37
North Carolina counties	.83	.39	.79	.50
Selected States	.70	.41	.61	.46
United States	.70	.65	.61	.83

1/ Proportion of crop sold forward to minimize revenue risk.
2/ Proportion of revenue variance eliminated by the hedge.

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INTRODUCTION

Farmers face uncertainty over crop revenues because crop yields and cash prices vary and are subject to risk. Farmers can manage revenue risk by selling forward in the futures or the cash forward markets. Viewed narrowly, forward selling reduces price risk, not yield risk. But such a narrow view ignores any correlation between price and yield. Although a farmer's output typically is too small to noticeably affect the market price, prices may move opposite to individual farm yields if such yields are correlated with yields on other farms. This relationship can be strong when the same weather, pests, or diseases affect many producers.

This report presents an analytical model of futures trading for corn and soybean producers with random yields. The model estimates price and yield risks for corn and soybeans, measures the interaction between them, and estimates the resulting revenue risk, the size of risk-minimizing futures positions, and the risk-reducing effectiveness of hedging. The estimates are based on county yield data for Iowa, Nebraska, and North Carolina; State yields for 19 producing States; and national yields.

The model in this report assumes that a farmer maximizes his/her one-period expected utility of income. The model assumes that income and futures prices are bivariate normal variables. This assumption produces a separation property like that generated in a mean/variance model: the utility-maximizing hedge is composed of a variance-minimizing component and an expected wealth-increasing component. One can measure the size of the variance-minimizing component. The expected wealth-increasing component is not measured here because it depends on each individual farmer's utility function and it may differ among farmers. Instead, the expected cost of trading futures is estimated and discussed.

The risk-minimizing hedge is partitioned into three parts: a price hedge, a yield hedge, and an interaction hedge. Each of these components minimizes the risk from a specific source: the random variation in spot prices, the random variation in yield, and the random variation in the interaction between price and yield.

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*The author is a professor at the Robert O. Anderson School and Graduate School of Management, University of New Mexico.

The model measures risk through variance of revenue. The degree of correlation between the market price and the farmer's output influences the variance of a farmer's revenue. A natural hedge results from a negative correlation; that is, revenue risk is lower than it would be if price and yield were independent. Revenue varies less if relatively high yields are sold at relatively low prices (and vice versa) than if yields and prices are unrelated.

RELATED STUDIES

McKinnon appears to have been the first to study the effects of price and yield interaction on hedging. He examined this issue in a mean/variance framework with futures trading and restricted his attention to the case in which price and yield are bivariate normal variables (20).1/

McKinnon's emphasis on price and quantity uncertainty is now widely incorporated in the analytical literature on commodity production (see 1, 2, 11, 14, 19, 24, 35). His variance-minimizing hedging result has been extended. The risk-minimizing hedge is the ratio of the covariance between revenue and the futures price to the variance of the futures price. There has been much less attention to yield uncertainty in the empirical literature on futures trading. Heifner, Rolfo, and Miller and Kahl have conducted relevant empirical studies (13, 31, 22).

Heifner examined soybean yield data for 10 counties from each of Iowa, Illinois, and Indiana, and aggregate data for the United States (13). His sample of counties reported in averages by State indicates that risk-minimizing hedge ratios were below 1. These low ratios were due to the negative correlation between yields and futures prices.

Rolfo examined the implications of yield uncertainty for hedging for cocoa producers (31). (Cocoa is an appealing commodity to study because its price, output, and the product of price and output are highly variable.) Rolfo studied price and production in Ghana, Nigeria, the Ivory Coast, and Brazil, which produce close to 80 percent of the world's annual output of cocoa. According to Rolfo, these countries would have minimized their variances of revenue in that period by selling short on the futures market 60.9, 65.4, 77.8, and 93.5 percent of their respective expected outputs.

Results generated by the national yield data are relevant for a national marketing agency, but results apply to individual producers only to the extent that national figures represent an individual's experiences. The extent to which they are representative is an important empirical question that is difficult to resolve, because data for individual producers are rarely available. We know that the aggregate of producers' hedges equals the hedge for the Nation because the hedge ratio is determined by the covariance between revenue and a futures price, and because covariances are additive. However, there may be systematic differences within the country caused, for example, by differences in weather patterns.

This report extends Heifner's and Rolfo's work in examining the effects of price and yield uncertainty on optimal futures positions for corn and soybean producers in the United States.

1/ Underscored numbers in parentheses refer to literature cited in the references section.

DECISION MODEL

I assumed the farmer maximizes his/her one-period expected utility of income from a single crop, given a scale of output and associated costs.2/ Realized yield and prices are random variables. The farmer's objective is expressed as:

$$\max_{h} EU(\pi) \tag{1}$$

where:

$$\pi = pq + h(f - F) \tag{2}$$

E is the expectations operator,
$U(\pi)$ is the utility function,
π is income,
p is the end-of-period local price of output,
q is the realized yield,
h is the quantity of futures sold (-) or bought (+),
f is the futures price at harvest, and
F is the futures price at planting.
π, p, q, and f, are random variables.

The hedge that maximizes the expected utility of income, h*, is a solution of the first-order condition, $\partial EU(\pi)/\partial h = 0$, when equation (2) is substituted into equation (1). By the chain rule, we have:

$$E[U'(\pi)(f - F)] = 0 \tag{3}$$

where: $U'(\pi) = \partial U(\pi)/\partial \pi$. Because the expected value of a product of two random variables is the product of their expected values, plus their covariance, we have:

$$EU'(\pi)E(f - F) + \text{cov}[U'(\pi),f] = 0 \tag{4}$$

Stein's theorem can be invoked if π and f are from bivariate normal distributions,

$$\text{cov}[U'(\pi),f] = EU''(\pi)\text{cov}(\pi,f) \tag{5}$$

where: $U''(\pi) = \partial U^2 (\pi)/\partial \pi^2$.3/ Referring to equation (2), we obtain:

$$EU''(\pi)\text{cov}(\pi,f) = EU''(\pi)[\text{cov}(pq,f) + (h)\text{var}(f)] \tag{6}$$

Substituting equation (6) into equation (5), inserting the result into equation (4), and solving for the optimal h yields:

2/ This report ignores the interaction between the choice of a scale of output and the choice of an optimal futures position. This report also ignores the case in which a farmer produces more than one commodity. For an analysis of the former issue, see (11). The latter issue is examined empirically in Grant and Eaker (12). These studies show that portfolios of certain spot positions in corn, oats, and wheat are as effectively hedged by matching futures to the spot positions as by a multivariate estimate of the optimal hedges. No one has studied hedging for portfolios of random yields.

3/ A simple statement of Stein's theorem is: $\text{cov}[U'(x),y] = EU''(x)\text{cov}(x,y)$, where: U is a twice differentiable continuous function and x and y are bivariate normal variables, see (32). See (34) for a more convenient reference.

$$h^* = -\,cov(pq,f)/var(f) - [EU'(\pi)E(f - F)]/[EU''(\pi)var(f)] \quad (7)$$

This result is similar to Rolfo's when he assumed a mean/variance objective function. The first term in equation (7), the variance-minimizing hedge, is the optimal hedge if futures are unbiased estimates of spot prices, $E(f - F) = 0$. (The variance-minimizing hedge is later referred to as the revenue risk-minimizing hedge.) Hedge estimates and estimates of $E(f - F)$ are discussed later.

The revenue risk-minimizing hedge can be separated into components. The first term of equation (7) can be written as:

$$h^* = -\,cov(pq,f)/var(f)$$

$$h^* = -\,[E(q)cov(p,f) + E(p)cov(q,f) + cov(\theta_p\theta_q,f)]/var(f) \quad (8)$$

where: $\theta_p = [p - E(p)]$, and $\theta_q = [q - E(q)]$. To interpret this expression, assume first that yield is certain; then $\theta_q = 0$, and the risk-minimizing hedge is the first term in equation (8):

$$h^* = (-q)cov(p,f)/var(f) \quad (9)$$

This familiar result [for example, see Ederington in (8)] is the hedge that minimizes price risk, where: the spot and futures positions are in like commodities, the correlation between p and f is close to 1, and the variances of p and f are approximately equal. In that case, $h^* \simeq -q$.

The second term of equation (8) is isolated if we assume the selling price is certain and the yield and the future price are risky (in this case, the futures contract could not be written in terms of the commodity with certain price, p). Then $\theta_p = 0$, and the risk-minimizing hedge is the second term in equation (8):

$$h^* = (-p)cov(q,f)/var(f) \quad (10)$$

Equation (10) corresponds to equation (9), and can be interpreted as the futures position that minimizes yield risk. The size of this hedge depends on the covariance between local yield and national futures prices. This covariance will be near zero unless yields are substantially correlated between localities, in which case the covariance should be negative. If negative, the covariance will reduce the absolute value of the optimal hedge relative to that obtained when yield is certain.

The third term of equation (8) affects the hedge when both price and yield are random. Then, the risk-minimizing hedge ratio contains the component that minimizes price risk, the component that minimizes yield risk, and

$$cov(\theta_p\theta_q,f)/var(f) \quad (11)$$

Equation (11) shows the influence of the interaction between price and yield. If p and f are highly positively correlated, then this component of the optimal hedge is likely to take the same sign as the correlation between p and q.

In addition to estimating risk-minimizing hedge ratios, this study reports measures of hedging effectiveness. Effectiveness is measured as the proportion of revenue variance eliminated by the hedge. The statistical measure of effectiveness is derived by substituting the definition of the risk-minimizing value for h into the expression for the variance of the hedged position:

$$\begin{aligned} var[pq + h(f - F)] &= var(pq) + 2(h)cov(pq,f) + (h^2)var(f) \\ &= var(pq) + [-2(cov(pq,f))^2 + (cov(pq,f))^2]/var(f) \\ &= var(pq)[1 - R^2(pq,f)] \end{aligned} \qquad (12)$$

where: R represents correlation. Equation (12) shows that the proportion of revenue risk eliminated by the risk-minimizing hedge is measured by the square of the correlation between revenue and the futures price.

The empirical work focuses on variance-minimizing hedges, and it is informative to examine in detail the expression for the variance of revenue. When p and q are correlated, the risk of revenue is:

$$\begin{aligned} var(pq) = {} & E^2(p)var(q) + E^2(q)var(p) + E(\theta_p{}^2\, \theta_q{}^2) + 2E(p)E(\theta_p\, \theta_q{}^2) + \\ & 2E(q)E(\theta_p{}^2\, \theta_q) + 2E(p)E(q)cov(p,q) - [cov(p,q,)]^2 \end{aligned} \qquad (13)$$

When p and q are statistically independent, the risk of revenue is:

$$var(pq) = E^2(p)var(q) + E^2(q)var(p) + var(p)var(q) \qquad (14)$$

[These results are derived in Goodman, see (10).] The two expressions differ because of the correlation between yields and prices. Equation (13) will likely be less than equation (14) if yields and prices are negatively correlated. This covariance provides a natural hedge: high prices offset low yields, and low prices offset high yields. The statistical measure of the risk reduction attributable to the natural hedge is defined similar to the hedging effectiveness measure (R^2) discussed above. The effectiveness of the natural hedge is 1 minus the ratio of equation (13) to equation (14). Effectiveness measures the reduction in variance, caused by the correlation between yields and prices, as a percentage of the variance that would have existed if prices and yields had not been correlated.

DATA

I estimated hedging relationships from 1961-83 data for corn and soybeans at four levels of aggregation: county and regional levels for Iowa, Nebraska, and North Carolina; State levels for 19 States; and the national level. Appendix tables 1, 3, 5, and 7 show the counties and States included in the study. Government programs affected corn prices more than soybean prices. The only effects of Government policy examined were observed changes in yields and market prices. Applicability of the results depends on the extent that future yield and price distributions, conditioned on Government policies, match the distributions of the study period.

Iowa and Nebraska were selected for the study because they are major corn- and soybean-growing areas. North Carolina is a minor corn- and soybean-growing area, and is likely to experience different growing conditions and different price relationships. Iowa and Nebraska ranked first and third in corn production in 1983, producing 18 and 11 percent, respectively, of U.S. corn output. Iowa's and Nebraska's shares of soybean output were 17 and 4 percent, where they ranked first and ninth. North Carolina produced only about 2 percent of the national output in each crop.

Counties in Iowa, Nebraska, and North Carolina were the primary units of analysis. County data were the least aggregated data available and provided the closest approximation to farm-level conditions.

Six counties were selected randomly from each of Iowa's nine districts. Every other county in Nebraska was selected, beginning with the first in each district. All North Carolina counties containing more than 10,000 acres of soybeans planted in 1982 and 1983 were included. The 19 States included those producing more than 15 million bushels of soybeans in 1983.

In addition to the county level analyses, data at the regional, State, and U.S. levels were examined to provide broader geographic coverage and insight into the effects of aggregation on the estimates. At issue is whether results based on U.S., State, regional, and county data can be applied to individual farms. Because the covariance between revenue and the futures price determines the risk-minimizing hedge, the hedge calculated from average county yield data is the weighted average of the hedges for the individual farms. The same is not true for the measures of risk and risk reduction because risks are not additive.

Time-series estimates of farmers' price and yield expectations would be the ideal data base for this study. Combined with harvesttime realizations, time-series estimates would permit analysis of the relevant relationships. But farmers' expectations are not directly observable. Therefore, futures market prices were used as proxies for farmers' conditional price expectations at planting time (these results were not sensitive to adjusting for the expected basis). Projected yields or historical average yields were used as proxies for the farmers' yield expectations.

Spot and futures price series were required for each location. One local spot price in each State was used for the county-level estimates. Because in-State prices were not available for all the States, Chicago spot prices were used for all the State aggregate estimates. All prices were observed at planting time (the first Thursday after May 15) and harvesttime (the first Thursday after October 15).4/ Futures and Chicago cash prices were drawn from the Chicago Board of Trade Statistical Annual and apply for Chicago delivery of No. 2 Yellow corn and No. 1 Yellow soybeans (5).

Prices for the county analyses were those paid to farmers for corn or soybeans delivered in bulk to an elevator located in the central region of Iowa near Des Moines, those paid in Omaha, and those paid in Wilson, North Carolina, for corn and in Raleigh, North Carolina, for soybeans. These prices were taken from various issues of the Des Moines Register, Grain Market News, Omaha World News, North Carolina Grain Market Report, and Raleigh News and Observer (7, 37, 27, 26, 30).

4/ Planting dates for soybeans were May 15-June 1 for the middle States, May 10-June 5 for the Central and Western States, and May 1-June 10 for the Southern States. Planting dates for corn were April 20-May 30 for the middle States, April 1-June 1 for the Central and Western States, and February-June for the Southern States. Maturation requires 16-20 weeks (5). Mid-May to mid-October seems a reasonable choice of dates for putting on and taking off hedges for the two crops. Soybean prices in Nebraska were the first available quotation after October 15.

The estimates in this report are based on proportional deviations in harvest-time prices and yields from planting time expectations. Deviations from expected values were used because the expected values of the price and yield series are not stable over time. Proportional deviations also facilitate interpretation of the results. All proportional changes in price are measured as the harvesttime value, divided by the conditional expectation of this price at planting time, minus 1. The conditional expectation is the futures price at planting time for delivery in December for corn or in November for soybeans. Hedge estimates are the variance-minimizing hedge divided by expected yield.

The calculations needed to estimate risk-minimizing hedge ratios involve the deviations of realized yields from expected yields. The yield data were taken from statistical reports issued by crop and livestock reporting services in Iowa, Nebraska, and North Carolina, and from Agricultural Statistics (17, 23, 25, 36). Expected yields at planting time were estimated either as the simple average yield for all 23 years or as predicted values derived from a linear regression of yields on time.5/

Corn yields rose over the period in every State and in virtually every county of Iowa, Nebraska, and North Carolina. By regressing yield on time, the null hypothesis of no growth was rejected for virtually all areas at a 5-percent confidence level. Therefore, the expected yields used in the analysis were those predicted by the trend regression equations.

Soybean yields in the Northern States generally exhibited statistically significant increases, while yields in the Southern States did not. The null hypothesis of no trend in soybean yields was rejected at a 5-percent confidence level for 52 of the 63 Iowa counties and regions and for the State. The null hypothesis was rejected for 24 of the 28 Nebraska counties. The null hypothesis was not rejected for 40 of 61 North Carolina counties and regions, nor for the State. The null hypothesis was rejected for 8 of the 19 States and for the United States (app. table 7 identifies States for which the null hypothesis was rejected). Therefore, expected soybean yields were derived from yield regressions for Iowa and Nebraska, but mean yields were used for North Carolina. Expected yields for States were based on regressions in States with statistically significant trends, while mean yields were used for other States.6/

5/ These approaches depend on data available only after the fact. This is a simple method of approximating farmers' conditional expectations. I did not investigate the sensitivity of these results to estimates based on more complex forecasting models or on models that use only data available to farmers.

6/ The results are not sensitive to the choice of the method for estimating the conditional expectations of yields. The weaker the estimated relationship, the less effect it had. It appears likely that where the null hypothesis of no growth was not rejected, the choice of model affected the risk-minimizing hedge by 2 to 3 percentage points. Using a logarithmic regression of yield on time hardly affected the results and fit the data slightly less well.

CORN RESULTS

Appendix tables 1-8 present estimates of yield risk, revenue risks, and risk-minimizing hedge ratios for corn.7/ Four sets of tables, one each for Iowa, Nebraska, North Carolina, and one for the State aggregates and U.S. results are included. The first table of each set provides estimates of corn and soybean yield and revenue risks over the growing season and the proportion of risk eliminated by the natural hedge. The second table in each set reports estimates of the risk-minimizing hedge ratios, their components, and the risk-shifting effectiveness of the hedges for corn. Appendix tables 9-12 report corresponding estimates for soybeans.

Iowa Counties

The standard deviation of actual/expected corn yield ranged from 9 to 25 percent among Iowa counties (app. table 1). Yields appear more variable in the southern districts of Iowa. The district and State estimates show that risk could be reduced by spreading production across counties. The standard deviation of yield risk was, for example, lower for the State data than for 42 of the 54 counties and was 4 percentage points lower than the average for all counties. The estimated standard deviations of actual/expected revenue ranged from 13 to 27 percent. Although these are large values, they are not as large as would exist if yield and price were not correlated. The estimated standard deviation of actual/expected price was 19 percent. Given this value, it is possible to calculate the effect of the natural hedge, which is reported in the third column and is measured as the complement of the ratio of the actual variance of revenue to that which would have existed if yield and price were stochastically independent [1 - equation (13)/equation (14)]. The natural hedge reduced revenue risk in every case. The range of reduction was from 13 percent to 63 percent, with an average of 30 percent.

The average revenue risk-minimizing hedge ratio for the 54 Iowa counties was 0.73 (app. table 2). (For convenience, the minus sign indicating a short position is omitted from the hedge ratios reported here and in subsequent tables.) All of the estimated hedge ratios were less than 1. All but one of the coefficients were signficantly different from zero, and 21 of 54 were significantly different from 1. In contrast, hedging studies that examine spot and futures positions in the same commodity when yield risk is absent produced estimates of risk-minimizing hedging ratios that were close to and often not significantly different from 1. The proportion of revenue risk eliminated by these hedges ranged from 11 percent to 85 percent, with an average of 57 percent. These values were also considerably lower than those calculated when yield risk was absent.

Appendix table 2 shows the three components, identified in equation (8), of the revenue risk-minimizing hedge ratio. The first term, cov(p,f)/var(f)--the risk-minimizing hedge ratio when quantity risk was ignored--was 0.92 for all counties, because the same price series was used for all. (Note that the minus sign was also dropped from the hedge ratio components.) This term

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7/ The risk measures reported in these and subsequent tables are standard deviations of proportional variations from planting time expectations. For example, the standard deviation for yield is the standard deviation of actual yield minus expected yield, divided by expected yield. This estimate simplifies to the standard deviation of actual yield divided by expected yield (actual/expected yield).

differed from 1 because of basis risk, but the difference was not statistically significant. Hedging at this level would have eliminated 95 percent of pure price risk. The second term, cov(q,f)/var(f), is the yield risk-minimizing hedge. All of the county coefficients were negative, and 5 were statistically different from zero. The fact that all estimates were negative supports the hypothesis that yields and prices were negatively correlated, even at the county level. On average, the negative covariance between yields and prices reduced the absolute size of the revenue risk-minimizing hedge ratio by 17 percentage points. The interaction effects were also predominately negative but smaller, and reduced the absolute size of the revenue hedge ratios by an average of 2 percentage points.

Nebraska Counties

The standard deviations of actual/expected corn yields in Nebraska ranged from 8 to 27 percent, with two extreme values of 33 percent (app. table 3). Yield variability exhibited no obvious geographic pattern. As in Iowa, the district and State aggregate measures of yield variabilities were lower than averages of their components, reflecting the effect of geographic diversification of yield.

The standard deviations of actual/expected revenue effectively ranged from 18 to 28 percent, with three outliers. The two counties with yield risk of 33 percent had revenue risk of 33 and 34 percent. These counties were joined at the extreme by a county with yield risk of 24 percent but a revenue risk of 39 percent. This extraordinarily large revenue risk results from the positive correlation between this county's yield and national prices in this sample. Whether the true correlation is positive is problematic. This case illustrates the importance of the natural hedge. For this county, the positive correlation between yield and price increased the county's revenue risk 57 percent over what it would have been if yield and price were not correlated. In contrast, the natural hedge reduced risk in all but 1 of the remaining 45 Nebraska counties. On average, excluding the one extreme value, risk was reduced by 22 percent. This effect was lower than Iowa's 30-percent effect, as might be expected, given Iowa's larger share of corn production. Combined with somewhat higher price risk, 20 versus 19 percent, and yield risk, 18 versus 16 percent, the smaller natural hedge produced a higher level of revenue risk, 24 versus 20 percent.

All of the estimated revenue risk-minimizing hedge ratios for corn in Nebraska were between zero and 1, except for the two counties that exhibited positive correlation between yields and prices (app. table 4). Thirteen of the county hedge ratios did not significantly differ from zero at the 5-percent confidence level, and 14 differed from 1. One of these county hedge ratios was greater than 1. The average hedge ratio for the counties was 68 percent, compared with 69 percent for the State. If one maintains the hypothesis that the true value of the optimal hedge ratio for each county was 69 percent (the aggregate estimate), then only one county estimate significantly differs from that value. The minimum-risk hedges would have eliminated, on average, 42 percent of the variance of revenue.

The hedge ratio that minimized price risk was 93 percent--not significantly different from 1. That ratio would have eliminated 91 percent of price risk. Negative correlations between yields and prices reduced the revenue hedge ratios for all but six counties. The average reduction was 21 percentage points. The interaction effect was also predominately negative, reducing the revenue hedge by an average of 0.04.

North Carolina Counties

The major corn-producing regions of North Carolina are near the Atlantic coast (note the number of counties from that area included in appendix table 5). There is much less cropland in the mountain and piedmont regions. Standard deviations of actual/expected corn yields, ranging from 13 to 33 percent and averaging 21 percent, were greater in North Carolina than in Iowa or Nebraska. The greater yield risk was reflected in greater revenue risk. Revenue risk was higher also because the natural hedge reduced average risk by only 21 percent.

The revenue risk-minimizing hedge ratios ranged from 0.42 to 1.1, with an average of 0.83 for the counties (app. table 6). All but one of the ratios significantly differed from zero. The exception was also the only estimate that significantly differed from 1. The risk-minimizing price hedge was 0.87. Like the price hedges for Iowa and Nebraska, this revenue risk-minimizing hedge did not differ from 1 at the 5-percent confidence level. The price hedge was only 0.04 greater than the average revenue hedge because the effects of yield uncertainty were much less pronounced in North Carolina than in Iowa and Nebraska. The average yield effect was -0.06, while the interaction increased the absolute size of the revenue hedge, on average, by 0.02. The low degrees of relationship between yields and prices also influenced the effectiveness of the revenue hedge. Hedging at the minimum-risk level would reduce the standard deviation of revenue, on average, by only 39 percent.

States

Variability of corn yields at the State level was generally lower in the Corn Belt and higher in the Southern States (app. table 7). For the States analyzed, Michigan had the lowest yield variation (9 percent) and Georgia had the highest (23 percent). The national yield variation was only 9 percent, indicating considerable diversification of yield risk across States.

Revenue risk ranged from 16 percent for Ohio to 30 percent for Georgia. The effect of using Chicago prices instead of local prices can be partly gauged by comparing the State estimates with estimates generated using local prices for Iowa, Nebraska, and North Carolina. The revenue risks from local prices were 20, 24, and 27 percent, respectively, compared with 20, 20, and 26 percent from Chicago prices. In two of the three cases, the Chicago prices provided similar estimates. The difference was somewhat larger in the third case.

The estimates of the effectiveness of the natural hedges were not as similar. With local prices, the effectiveness was 36, 21, and 21 percent, while it was 28, 30, and -1 percent with Chicago prices. These results raise a question about the accuracy of individual estimates, but the overall results in appendix table 7 suggest that the natural hedge is an important determinant of revenue risk. On average, the natural hedge reduced State revenue variation by 40 percent.

Estimated minimum-risk hedge ratios for corn were less than 1 for all 19 States; and ratios for 7 of the 19 States significantly differed from 1 (app. table 8). The average ratio was 0.70, the same as obtained by using U.S. aggregate yields. On average, these hedges eliminated 41 percent of the revenue risk.

Yield hedges accounted for most of the geographic variance. All of the yield hedges were negative. Yield hedges for five States and the United States significantly differed from zero. The average value for the States was the same as for the country as a whole, 0.24. Therefore, the negative covariance between yields and futures prices reduced the revenue hedge by 0.24 below the price hedge. The interaction effects ranged between 0.05 and -0.08 percent with an average value of -0.03 percent.

The effects of using Chicago prices rather than local prices can be examined by comparing results in appendix table 8 with the corresponding results for Iowa, Nebraska, and North Carolina from earlier tables. Spot prices do not enter into the calculation of the yield hedge. Therefore, the yield hedge estimates based on Chicago and local prices are the same. The interaction hedges were typically quite small and not an important source of differences. Interaction hedges from local prices were -0.02, -0.03, and 0.02 for Iowa, Nebraska, and North Carolina, respectively. Interaction hedges from Chicago prices were -0.04, -0.05, and 0.05. The differences created by the price hedge were somewhat larger. Price hedges from local prices for the three States were 0.92, 0.93, and 0.87. The Chicago price hedge was 0.97. From these estimates, we would expect somewhat greater basis risk at distant market sites. This degree of difference does not materially affect the risk-reducing performance of hedges.

The estimates of risk reduction also vary with the choice of spot price series. The proportion risk reduction using local prices was 0.71, 0.52, and 0.57 for the three States. Values with Chicago prices were 0.59, 0.49, and 0.53. Chicago prices may slightly understate the effectiveness of hedging. Taken together, these results suggest that Chicago prices may be reasonable proxies for estimating hedge ratios when local prices are not readily available. But more research is needed to confirm whether proxies can be substituted.

SOYBEAN RESULTS

Appendix tables 1, 3, 5, and 7 present estimates of price and yield variability for soybeans. The estimated minimum-risk hedge ratios are presented in appendix tables 9-12.

Iowa Counties

Yield risk was lower for soybeans than corn in Iowa. Estimated standard deviations of county actual/expected soybean yields ranged from 6 to 16 percent, with an average of 10 percent (app. table 1). Yield risk was only 7 percent for the State. The standard deviation of actual/expected soybean prices in Iowa was 17 percent. When the yield and price risks were combined, they produced revenue risk varying from 13 to 20 percent, with an average of only 16 percent (less than the price risk alone). These values were relatively small because the natural hedge was large. The negative correlation between yields and prices reduced the risk in every county. On average, the variance of revenue was 35 percent lower than if yield and price were not correlated.

All of the county-level minimum-risk hedge ratios were less than 1 (app. table 9). All significantly differed from zero. Thirty-three of the 54 county ratios also significantly differed from 1; these counties were concentrated in the central and southern districts, where the hedge ratios for 29 of the 36 counties significantly differed from 1. The average hedge ratio for the counties was 0.73, only slightly less than the 0.76 ratio estimated from State data. The risk-minimizing hedge ratios eliminated an average of 65 percent of the variance in county revenue.

Sources of differences in the risk-minimizing hedge ratios were revealed by partitioning the hedge ratios into the three components identified in equation (8): the price hedge, the yield hedge, and the interaction hedge. The price hedge ratio was 0.96; all of the revenue hedge ratios were lower because all but one of the yield and interaction hedges were negative. The price-yield correlation reduced the revenue hedge, relative to the price hedge, by 0.18 on average. This effect was strongest in the southern regions where 7 of the 18 yield hedges significantly differed from zero. The interaction effect reduced the optimal hedge by an average of 0.06. The interaction effect significantly differed from zero in all 18 counties in the southern region, 14 of the 18 counties in the central region, and 6 of 18 counties in the northern region.

These results suggest several things about risk-minimizing hedge ratios at planting time for soybeans in Iowa. In the absence of yield uncertainty, the best hedge would be relatively close to the size of the cash position. Basis risk reduces the hedge by about 4 percent. Yield and interaction effects reduce the price hedge an additional 24 percent (measured at the county level). Yield effects appear to be strongest in the southern regions, somewhat weaker in the central regions, and weakest in the northern regions.

Nebraska Counties

Complete soybean yield data were available for only 28 of the 46 Nebraska counties studied (app. table 3). These soybean-growing counties are concentrated in the three eastern regions of the State. The standard deviations of actual/expected soybean yields ranged between 8 and 22 percent, with one extreme value at 36 percent. The average value was 17 percent, nearly the same as for corn but 7 percentage points higher than the average for Iowa soybeans. Revenue risk was relatively small given the yield risk. The standard deviations of revenue ranged from 17 to 23 percent, with an extreme value at 33 percent. The correlation between yield and price reduced revenue risk for every county and district. On average, revenue risk was 40 percent lower than it would have been if soybean yields and prices in Nebraska were stochastically independent.

The average risk-minimizing hedge ratio for Nebraska counties was 0.65 (app. table 10). Estimates for three counties did not significantly differ from zero, and five significantly differed from 1. The relatively large standard errors of the estimates caused the absence of statistical significance. On average, the county hedges would reduce revenue risk by 37 percent.

The minimum-risk price hedge ratio estimated with Omaha prices was 1.08. Therefore, the low values for the revenue hedge occurred despite the high estimate for the price hedge. The yield hedges for counties were relatively large, reducing the price hedge by an average of 0.38. This component of the hedge was uniformly negative for the individual counties and was statistically significant in half of the counties. The interaction hedge was also uniformly negative and reduced the county hedges by up to 0.09, the average being 0.03.

North Carolina Counties

The standard deviations of actual/expected yields for soybeans in North Carolina ranged from 8 to 26 percent, with an average of 14 percent (app. table 5). Combined with a 17-percent standard deviation of actual/expected price, yield variability produced revenue risk ranging from 16 to 28 percent, with an average value of 21 percent. All but two measures of the natural hedge effect were positive, and the correlation between yield and price reduced risk by an average of 22 percent.

The average county risk-minimizing hedge ratio, 0.79, was slightly higher than for Iowa (app. table 11). The ratio estimated with State yields was 0.76. Only 2 of the 53 counties in North Carolina had a ratio larger than 1, while 5 of the estimated county hedge ratios for North Carolina significantly differed from 1. The price risk-minimizing hedge, 0.98, was approximately the same as for Iowa, but smaller than for Nebraska. The yield hedges were negative with three exceptions. Yield hedges reduced the absolute size of the revenue hedge by 0.14 on average. Sixteen of the interaction hedges statistically differed from zero, but only one was positive. On average, the interaction hedges reduced the revenue hedge by 0.04. The revenue hedges reduced revenue variance by an average of 50 percent.

States

Yield variability measured at the State aggregate level was higher for soybeans than for corn (app. table 7). Iowa exhibited the lowest standard deviation of yield (7 percent), and Kansas exhibited the highest (22 percent). State estimates averaged 13 percent, compared with 7 percent using U.S. aggregate data. Revenue risk varied from 10 percent in Illinois to 29 percent in Georgia. The value for Illinois is notable because the correlation between yields in Illinois and national prices reduced its revenue risk by 76 percent. As with corn, all soybean estimates were based on Chicago spot prices. The values estimated from Chicago soybean prices were similar to those from local soybean prices for Iowa, Nebraska, and North Carolina (revenue risk based on Chicago prices was: 15, 16, and 17 percent versus 16, 18, and 20 percent when based on local prices; natural hedges based on Chicago prices were 38, 53, and 29 percent versus 36, 49, and 21 percent when based on local prices). Values may not be as close in other States. The risk-reducing effect of the natural hedge in soybeans was relatively large (except in Georgia and Louisiana), averaging 50 percent for the other 17 States.

The correlation between yields and futures prices was negative for all 19 States and significantly different from zero for 12 States (app. table 12). This relationship reduced the hedge ratio by an average of 0.33. The interaction effects were also negative in all but three cases.

SENSITIVITY TESTS

The hedging effectiveness measures were based on hedge ratios calculated from data for the entire sample period, whereas actual hedging decisions in any given period can only use information from previous periods. A preferred measure of effectiveness would be based on a hedge ratio determined from previous observations only. Such out-of-sample measures of effectiveness would be less than or equal to the in-sample estimates because of errors in estimates and changes over time in the risk-minimizing hedge ratio. Out-of-sample tests were not performed because the data requirements for out-of-sample testing are considerable, and only one observation per year is possible.

The sensitivity of the hedging effectiveness measure to variations in the hedge ratio was examined in lieu of out-of-sample testing. This sensitivity test provided insight into the likely effects of estimation errors and changes over time in the hedge ratios. The proportion of risk reduced was calculated for 10 arbitrary hedge ratios (0.10, 0.20, . . . 1.00) for corn and soybeans in each county and State. The results were similar across States and commodities (app. table 13). Appendix table 13 reports the effectiveness measures for one county each from Iowa, Nebraska, and North Carolina; for one other State; and for the United States. The counties chosen had optimal hedge ratios and effectiveness measures close to the State averages. The States chosen had measures close to the averages of the States.

The proportion of risk eliminated was not sensitive to moderate deviations from the variance-minimizing hedge ratio. The proportion of risk eliminated was essentially constant for hedge ratios within 5 percentage points of the risk-minimizing ratio. Effectiveness declined only 1 to 3 percentage points when the hedge ratio deviated 10 percentage points from its optimum; the effectiveness was typically reduced by only 3 to 6 percentage points even for deviations of 20 percentage points.

COST OF HEDGING

The second component of equation (7), $-[EU'(\pi)E(f - F)]/[EU''(\pi)var(f)]$, thus far has been ignored. The hedges estimated are optimal if the futures price at planting time, F, is an unbiased estimate of the futures price of the same contract at harvesttime, E(f). If E(f) is greater than F, the farmer sells less of the expected output in the futures market because selling futures decreases the expected revenue. (Note that $EU''(\pi)$ is less than zero.) If E(f) is less than F, the farmer sells more of the expected output in the futures market because selling futures increases the expected revenue.

For the period studied, the mean values of (f - F) were 3.36 percent for corn and 5.29 percent for soybeans. The estimated standard deviations were 20.1 percent and 17.6 percent, respectively. The null hypothesis that E(f) = F was not rejected at the usual levels of significance in either case because the t-values were 0.80 for corn and 1.44 for soybeans. The optimal hedge would be less than the risk-minimizing level reported here, if farmers believe futures prices at planting time are lower than expected cash price at harvesttime. While not statistically significant, the average cost of hedging for this period might be perceived as economically important. If so, the preferred level of short sales may be considerably less than the variance-minimizing level.

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Appendix table 1--Proportional risks in yield and revenue over the growing season and the effect of the natural hedge for corn and soybeans grown in selected Iowa counties, 1961-83

District and county	Corn			Soybeans		
	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/
Northwest:						
Buena Vista	0.14	0.19	0.32	0.11	0.17	0.35
Clay	.14	.18	.41	.11	.17	.33
Emmet	.14	.20	.19	.11	.20	.07
Obrien	.15	.21	.18	.14	.19	.26
Palo Alto	.13	.19	.24	.09	.18	.16
Pocahontas	.14	.20	.24	.11	.18	.26
District	.14	.19	.34	.10	.17	.39
North Central:						
Butler	.10	.17	.33	.06	.16	.23
Floyd	.14	.18	.40	.09	.16	.34
Hancock	.11	.17	.39	.07	.17	.21
Kossuth	.11	.19	.20	.07	.19	.04
Winnebago	.12	.18	.30	.09	.17	.25
Wright	.10	.18	.29	.06	.15	.31
District	.10	.17	.31	.06	.16	.24
Northeast:						
Allamakee	.10	.19	.21	.11	.17	.29
Bremer	.09	.17	.32	.06	.17	.18
Chickasaw	.14	.19	.33	.11	.17	.33
Delaware	.10	.16	.42	.09	.16	.36
Fayette	.10	.19	.19	.08	.18	.10
Winneshiek	.12	.19	.22	.12	.18	.30
District	.09	.17	.33	.08	.16	.20
West Central:						
Calhoun	.13	.19	.24	.10	.18	.25
Crawford	.19	.22	.26	.09	.16	.34
Guthrie	.17	.19	.37	.11	.16	.39
Ida	.22	.24	.20	.11	.16	.43
Sac	.17	.22	.20	.10	.16	.40
Woodbury	.20	.22	.30	.14	.17	.40
District	.15	.19	.31	.09	.15	.40
Central:						
Dallas	.18	.21	.28	.11	.17	.31
Hamilton	.12	.18	.23	.10	.16	.34
Jasper	.16	.21	.24	.09	.16	.37
Polk	.15	.19	.33	.11	.17	.36
Story	.18	.24	.19	.13	.19	.24
Webster	.11	.19	.22	.09	.16	.30
District	.12	.20	.18	.08	.17	.26

See footnotes at end of table.

Continued--

Appendix table 1--Proportional risks in yield and revenue over the growing season and the effect of the natural hedge for corn and soybeans grown in selected Iowa counties, 1961-83--Continued

District and county	Corn			Soybeans		
	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/
East Central:						
Benton	0.11	0.18	0.32	0.06	0.17	0.20
Clinton	.12	.13	.63	.10	.13	.59
Iowa	.15	.17	.43	.09	.14	.47
Johnson	.12	.15	.55	.08	.13	.52
Jones	.11	.15	.50	.08	.14	.49
Muscatine	.10	.15	.49	.08	.15	.38
District	.11	.14	.54	.07	.14	.46
Southwest:						
Adair	.19	.20	.36	.09	.16	.30
Cass	.19	.20	.38	.08	.15	.42
Fremont	.20	.22	.27	.09	.17	.29
Montgomery	.17	.19	.38	.09	.16	.38
Pottawattamie	.18	.19	.41	.08	.14	.43
Taylor	.25	.24	.37	.14	.16	.49
District	.18	.20	.38	.08	.15	.41
South Central:						
Appanoose	.24	.26	.17	.15	.16	.51
Decatur	.24	.25	.21	.16	.17	.46
Madison	.21	.22	.31	.13	.18	.31
Monroe	.24	.25	.23	.16	.18	.42
Union	.23	.23	.34	.13	.18	.34
Wayne	.24	.26	.17	.14	.17	.46
District	.22	.23	.28	.13	.16	.43
Southeast:						
Davis	.25	.27	.13	.16	.18	.44
Henry	.17	.21	.29	.10	.14	.51
Keokuk	.20	.23	.23	.11	.15	.48
Louisa	.14	.19	.30	.10	.14	.49
Van Buren	.22	.25	.16	.10	.15	.44
Washington	.15	.17	.46	.10	.14	.51
District	.17	.21	.28	.09	.14	.51
State	.12	.17	.35	.07	.15	.36
County average	.16	.20	.30	.10	.16	.35

1/ Standard deviation of actual yield/expected yield.

2/ Standard deviation of actual revenue/expected revenue. The estimated standard deviations of actual price/expected price for corn and soybeans are 0.19 and 0.17, respectively.

3/ Proportional reduction in revenue variance due to negative correlation between price and yield.

Appendix table 2--Estimates of revenue risk-minimizing hedge ratios and their components for corn grown in selected Iowa counties, 1961-83

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/ Yield risk	Component 1/ Interaction risk
Northwest:					
Buena Vista	0.75	6.20	0.65	0.19	0.02
Clay	.65*	5.06	.55	-.23	-.04
Emmet	.85*	6.99	.69	-.07	0
Obrien	.77	4.97	.54	-.13	-.02
Palo Alto	.83	7.81	.74	-.09	0
Pocahontas	.82	6.91	.69	-.12	.02
District	.69	5.22	.56	-.21	-.01
North Central:					
Butler	.76	9.20	.80	-.13	-.02
Floyd	.66*	5.10	.55	-.24	-.02
Hancock	.73*	8.71	.61	-.17	-.02
Kossuth	.84	9.18	.80	-.07	0
Winnebago	.75*	6.93	.70	-.14	-.02
Wright	.80*	10.15	.83	-.11	-.01
District	.76*	9.22	.80	-.12	-.02
Northeast:					
Allamakee	.82	9.01	.79	-.09	-.01
Bremer	.78*	10.75	.85	-.14	0
Chickasaw	.73*	5.74	.61	-.17	-.03
Delaware	.72*	9.93	.82	-.19	-.01
Fayette	.86	10.61	.84	-.05	-.01
Winneshiek	.82	7.90	.75	-.08	-.01
District	.77*	10.42	.84	-.13	-.01
West Central:					
Calhoun	.83	8.11	.76	-.08	-.01
Crawford	.69	3.84	.41	-.22	-.01
Guthrie	.66*	4.37	.48	-.21	-.05
Ida	.72	3.41	.36	-.25	.05
Sac	.80	5.12	.56	-.15	.03
Woodbury	.60	3.09	.31	-.33	.01
District	.70	4.92	.54	-.20	-.02
Central:					
Dallas	.79	5.40	.58	-.09	-.03
Hamilton	.85	9.08	.80	-.05	-.02
Jasper	.83	6.34	.66	-.06	-.02
Polk	.73	5.69	.61	-.15	-.04
Story	0	7.60	.73	-.12	-.03
Webster	.85	9.82	.82	-.06	-.01
District	.88	9.04	.80	-.01	-.02

See footnotes at end of table.

Continued--

Appendix table 2--Estimates of revenue risk-minimizing hedge ratios and their their components for corn grown in selected Iowa counties, 1961-83--Continued

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
East Central:					
Benton	0.77*	8.48	0.77	-0.15	0
Clinton	.50*	5.41	.58	-.38**	-.04
Iowa	.67*	5.58	.60	-.23	-.02
Johnson	.60*	6.61	.49	-.32**	0
Jones	.65*	7.89	.75	-.25**	-.02
Muscatine	.63*	6.96	.70	-.30**	-.01
District	.61*	7.62	.73	-.29**	-.01
Southwest:					
Adair	.65	3.90	.42	-.22	-.05
Cass	.50*	2.69	.26	-.35	-.07
Fremont	.66	3.37	.35	-.19	-.07
Montgomery	.57*	3.41	.36	-.30	-.05
Pottawattamie	.43*	2.31	.20	-.40**	-.18
Taylor	.40*	1.64	.11	-.46	-.16
District	.53*	2.95	.29	-.32	-.17
South Central:					
Appanoose	.77	3.41	.36	-.14	0
Decatur	.74	3.42	.36	-.16	-.02
Madison	.74	4.19	.46	-.12	-.06
Monroe	.79	3.72	.40	-.08	-.04
Union	.62	3.03	.30	-.22	-.07
Wayne	.84	3.81	.41	-.07	-.01
District	.76	4.03	.44	-.12	-.04
Southeast:					
Davis	.84	3.65	.39	-.09	.01
Henry	.73	4.68	.51	-.21	.02
Keokuk	.79	4.43	.48	-.14	.01
Louisa	.75	6.01	.63	-.19	.02
Van Buren	.83	4.18	.45	-.10	.01
Washington	.63*	4.88	.53	-.29	-.01
District	.75	4.92	.54	-.17	.01
State	.72*	7.28	.71	-.17	-.02
County average	.73	NA	.57	-.17	-.02

NA = Not applicable.

*Significantly different from 1 at the 5-percent confidence level.

**Significantly different from zero at the 5-percent confidence level.

1/ The price risk-minimizing hedge ratio is 0.92 at Des Moines. The standard error is 0.047, and the R^2 is 0.95.

Appendix table 3--Proportional risks in yield and revenue over the growing season and the effect of the natural hedge for corn and soybeans grown in selected Nebraska counties, 1961-83

District and county	Corn: Yield risk 1/	Corn: Revenue risk 2/	Corn: Natural hedge effect 3/	Soybeans: Yield risk 1/	Soybeans: Revenue risk 2/	Soybeans: Natural hedge effect 3/
Northwest:						
Banner	0.20	0.25	0.19	NA	NA	NA
Cheyenne	.10	.21	.12	NA	NA	NA
Deuel	.09	.20	.14	NA	NA	NA
Kimball	.18	.25	.10	NA	NA	NA
Scotts Bluff	.11	.19	.28	NA	NA	NA
Sioux	.12	.21	.14	NA	NA	NA
District	.08	.19	.21	NA	NA	NA
North:						
Boyd	.26	.28	.24	0.36	0.33	0.37
Cherry	.22	.27	.20	NA	NA	NA
Logan	.15	.21	.26	NA	NA	NA
McPherson	.33	.33	.27	NA	NA	NA
Thomas	.24	.39	-.61	NA	NA	NA
District	.11	.23	-.03	.17	.27	-.06
Northeast:						
Antelope	.17	.18	.52	.19	.23	.31
Burt	.23	.26	.23	.16	.18	.50
Cuming	.25	.28	.23	.17	.21	.41
Dixon	.27	.28	.31	.21	.22	.43
Madison	.20	.24	.27	.18	.21	.42
Stanton	.24	.27	.27	.20	.21	.47
Wayne	.26	.26	.37	.22	.24	.37
District	.21	.23	.36	.18	.21	.44
Central:						
Buffalo	.10	.21	.12	.08	.20	.22
Dawson	.08	.19	.20	.15	.23	.15
Hall	.11	.21	.11	.09	.17	.42
Sherman	.13	.18	.40	.13	.19	.43
District	.10	.20	.20	.07	.18	.32
East:						
Butler	.17	.23	.25	.18	.20	.47
Colfax	.21	.23	.34	.17	.20	.41
Douglas	.23	.26	.25	.13	.20	.32
Lancaster	.22	.23	.36	.17	.19	.47
Nance	.15	.20	.36	.15	.22	.24
Polk	.14	.21	.25	.13	.20	.36
Saunders	.26	.27	.30	.18	.21	.42
Washington	.22	.25	.30	.14	.18	.50
District	.16	.21	.32	.15	.19	.45

See footnotes at end of table.

Continued--

Appendix table 3--Proportional risks in yield and revenue over the growing season and the effect of the natural hedge for corn and soybeans grown in selected Nebraska counties, 1961-83--Continued

District and county	Corn			Soybeans		
	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/
Southwest:						
Chase	0.14	0.26	0.14	NA	NA	NA
Frontier	.17	.26	-.02	NA	NA	NA
Hitchcock	.15	.24	.05	NA	NA	NA
Lincoln	.11	.19	.32	NA	NA	NA
Red Willow	.13	.22	.12	NA	NA	NA
District	.12	.20	.21	0.13	0.19	0.36
South:						
Adams	.11	.21	.17	.14	.17	.53
Furnas	.11	.22	.05	NA	NA	NA
Harlan	.13	.23	.01	NA	NA	NA
Phelps	.09	.21	.07	.09	.20	.21
District	.10	.21	.11	.10	.16	.55
Southeast:						
Clay	.12	.23	.02	.16	.20	.40
Gage	.19	.20	.42	.19	.19	.53
Johnson	.26	.26	.38	.21	.22	.45
Nuckolls	.12	.21	.15	.17	.22	.30
Pawnee	.33	.34	.24	.21	.21	.49
Saline	.16	.22	.27	.19	.20	.48
District	.15	.20	.34	.15	.17	.55
State	.12	.19	.19	.15	.18	.48
County average	.18	.24	.21	.17	.21	.40

NA = Soybean yields were not available for these counties.

1/ Standard deviation of actual yield/expected yield.

2/ Standard deviation of actual revenue/expected revenue. The estimated standard deviations of actual price/expected price for corn and soybeans are both 0.20.

3/ Proportional reduction in revenue variance due to negative correlation between price and yield.

Appendix table 4--Estimates of revenue risk-minimizing hedge ratios and their components for corn grown in selected Nebraska counties, 1961-83

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/ Yield risk	Interaction risk
Northwest:					
Banner	0.79	3.67	0.39	-0.10	-0.04
Cheyenne	.88	7 60	.73	-.05	0
Deuel	.87	8.70	.78	-.04	-.02
Kimball	.96	5.29	.57	.03	-.01
Scotts Bluff	.79	6.78	.69	-.11	-.03
Sioux	.88	6.67	.68	-.04	-.02
District	.84	9.23	.80	-.07	-.02
North:					
Boyd	.53	1.87	.14	-.37	-.03
Cherry	.77	3.28	.34	-.15	-.01
Logan	.68	3.91	.42	-.22	-.03
McPherson	.34	.95	.04	-.51	-.08**
Thomas	1.61	6.64	.68	.55	.13**
District	.98	8.10	.76	.02	-.03
Northwest:					
Antelope	.42*	2.37	.21	-.43**	-.08**
Burt	.49	1.83	.14	-.36	-.08
Cuming	.41	1.41	.09	-.44	-.07
Dixon	.28*	.96	.04	-.55	-.10
Madison	.50*	2.15	.18	-.35	-.08
Stanton	.40*	1.46	.08	-.46	-.07
Wayne	.20*	.71	.02	-.62**	-.11
District	.41*	1.77	.13	-.44**	-.08
Central:					
Buffalo	.88	7.82	.74	-.04	0
Dawson	.83	8.31	.77	-.08	-.02
Hall	.87	6.75	.68	-.05	-.01
Sherman	.62*	4.34	.47	-.25	-.06**
District	.82	7.23	.71	-.09	-.02
East:					
Butler	.61	2.92	.29	-.28	-.04
Colfax	.41*	1.73	.13	-.45**	-.07
Douglas	.46*	1.70	.12	-.37	-.10
Lancaster	.39*	1.64	.11	-.46**	-.08
Nance	.63	3.81	.41	-.25	-.05
Polk	.73	4.51	.49	-.20	-.01
Saunders	.29*	.99	.46	-.57**	-.08
Washington	.39*	1.52	.10	-.43	-.11
District	.62	3.45	.36	-.27	-.04

See footnotes at end of table.

Continued--

Appendix table 4--Estimates of revenue risk-minimizing hedge ratios and their components for corn grown in selected Nebraska counties, 1961-83--Continued

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
Southwest:					
Chase	1.06	6.73	0.68	0.10	0.03
Frontier	.98	5 48	.59	.03	.03
Hitchcock	.92	5.74	.61	-.04	.03
Lincoln	.73	5.97	.63	-.18	-.02
Red Willow	.88	6.06	.64	-.09	.04
District	.80	5.87	.62	-.14	.01
South:					
Adams	.85	6.81	.69	-.08	0
Furnas	.90	8.82	.69	-.04	.01
Harlan	.96	6.63	.68	.01	.02
Phelps	.91	8.42	.77	-.02	0
District	.89	7.57	.73	-.04	0
Southeast:					
Clay	.94	6.58	.67	0	.01
Gage	.51*	2.63	.25	-.36	-.06
Johnson	.30*	1.12	.06	-.56**	-.07
Nuckolls	.85	6.44	.66	-.06	-.02
Pawnee	.35	.98	.04	-.51	-.07
Saline	.73	4.20	.46	-.17	-.03
District	.65	3.92	.42	-.24	-.04
State	.69*	4.77	.52	-.21	-.03
County average	.68	NA	.42	-.21	-.04

NA = Not applicable.
*Significantly different from 1 at the 5-percent confidence level.
**Significantly different from zero at the 5-percent confidence level.
1/ The price risk-minimizing hedge ratio is 0.93 at Omaha. The standard error is 0.063, and the R^2 is 0.91.

Appendix table 5--Proportional risks in yield and revenue over the growing season and the effect of the natural hedge for corn and soybeans grown in selected North Carolina counties, 1961-83

District and county	Corn Yield risk 1/	Corn Revenue risk 2/	Corn Natural hedge effect 3/	Soybeans Yield risk 1/	Soybeans Revenue risk 2/	Soybeans Natural hedge effect 3/
North Coastal:						
Bertie	0.24	0.28	0.22	0.14	0.20	0.23
Camden	.13	.21	.16	.11	.21	-.02
Chowan	.20	.26	.13	.11	.18	.27
Currituck	.12	.21	.18	.11	.19	.15
Edgecombe	.25	.29	.15	.11	.18	.27
Gates	.26	.27	.34	.15	.20	.26
Halifax	.23	.25	.32	.17	.22	.23
Hertford	.23	.25	.32	.16	.20	.33
Martin	.19	.22	.38	.13	.19	.26
Nash	.27	.28	.31	.17	.20	.36
Northampton	.27	.29	.23	.15	.18	.45
Pasquotank	.15	.21	.23	.08	.18	.18
Perquimans	.18	.27	.15	.10	.19	.18
Tyrell	.16	.23	.18	.12	.25	-.31
Washington	.18	.25	.13	.09	.18	.18
District	.18	.23	.27	.08	.17	.26
Central Coastal:						
Beaufort	.14	.23	.09	.08	.18	.17
Carteret	.19	.26	.10	.08	.16	.31
Craven	.22	.25	.25	.12	.17	.39
Greene	.21	.26	.20	.15	.21	.23
Hyde	.14	.25	-.09	.10	.19	.11
Johnston	.24	.26	.28	.18	.22	.29
Jones	.20	.26	.17	.11	.18	.29
Lenoir	.20	.25	.20	.12	.16	.45
Pamlico	.14	.21	.26	.09	.18	.21
Pitt	.20	.22	.38	.14	.19	.31
Wayne	.20	.25	.19	.12	.20	.19
Wilson	.21	.27	.16	.18	.24	.16
District	.17	.23	.23	.09	.17	.33
South Coastal:						
Bladen	.21	.26	.22	.12	.20	.20
Brunswick	.16	.25	-.02	.10	.19	.13
Columbus	.17	.24	.16	.11	.19	.19
Cumberland	.24	.30	.06	.13	.21	.17
Duplin	.16	.23	.13	.09	.18	.23
Harnett	.30	.34	.10	.17	.23	.20
Hoke	.23	.25	.29	.16	.21	.27
New Hanover	.15	.24	.02	.08	.19	.04
Onslow	.17	.26	.01	.08	.19	.11
Pender	.19	.24	.23	.11	.19	.21

See footnotes at end of table.

Continued--

Appendix table 5--Proportional risks in yield and revenue over the growing season and the effect of the natural hedge for corn and soybeans grown in selected North Carolina counties, 1961-83--Continued

	Corn			Soybeans		
District and county	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/
South Coastal (continued):						
Robeson	0.23	0.26	0.23	0.16	0.21	0.21
Sampson	.20	.26	.13	.11	.20	.14
Scotland	.27	.30	.19	.19	.21	.37
District	.19	.25	.13	.11	.18	.24
North Mountain:						
Yadkin	.19	.24	.21	.18	.23	.23
District	.18	.24	.18	.16	.21	.25
West Mountain:						
Rutherford	.19	.23	.28	.15	.18	.42
District	.11	.20	.22	.13	.17	.43
North Piedmont:						
Franklin	.26	.27	.33	.22	.23	.41
Vance	.23	.23	.41	.21	.22	.37
Warren	.24	.25	.36	.20	.22	.39
District	.21	.24	.32	.17	.20	.40
Central Piedmont:						
Rowan	.27	.31	.14	.24	.28	.16
Wake	.26	.28	.27	.19	.23	.25
District	.22	.25	.28	.17	.22	.24
South Piedmont:						
Anson	.28	.29	.27	.20	.24	.24
Cleveland	.25	.29	.17	.18	.25	.07
Lincoln	.29	.34	.17	.19	.25	.09
Richmond	.26	.25	.40	.21	.24	.28
Stanly	.28	.31	.20	.21	.26	.13
Union	.33	.35	.16	.21	.25	.16
District	.26	.28	.25	.18	.24	.17
State	.17	.22	.25	.09	.17	.33
County average	.21	.26	.20	.14	.20	.23

1/ Standard deviation of actual yield/expected yield.

2/ Standard deviation of actual revenue/expected revenue. The estimated standard deviations of actual price/expected price for corn and soybeans are 0.19 and 0.17, respectively.

3/ Proportional reduction in revenue variance due to negative correlation between price and yield.

Appendix table 6--Estimates of revenue risk-minimizing hedge ratios and their components for corn grown in selected North Carolina counties, 1961-83

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/ Yield risk	Component 1/ Interaction risk
North Coastal:					
Bertie	0.84	3.54	0.37	-0.08	0.05
Camden	.86	6.31	.65	-.05	.03
Chowan	.93	4.64	.51	-.02	.07
Currituck	.83	6.16	.64	-.08	.03
Edgecombe	.92	3.79	.41	0	.05
Gates	.67	2.70	.26	-.23	.03
Halifax	.69	3.08	.31	-.23	.05
Hertford	.73	3.29	.34	-.16	.02
Martin	.71	4.02	.43	-.16	.02
Nash	.69	2.68	.25	-.18	.04
Northampton	.79	2.94	.29	-.11	.02
Pasquotank	.83	5.73	.61	-.07	.03
Perquimans	.90	5.13	.55	-.02	.05
Tyrell	.90	5.86	.62	0	.02
Washington	.93	5.39	.58	.02	.04
District	.80	4.62	.50	-.10	.03
Central Coastal:					
Beaufort	.96	6.87	.69	.07	.01
Carteret	.98	5.28	.57	.08	.03
Craven	.83	3.99	.43	-.06	.01
Greene	.89	4.39	.48	0	.02
Hyde	1.10	8.32	.77	.20	.03
Johnston	.71	2.95	.29	-.19	.03
Jones	.91	4.69	.51	.03	.01
Lenoir	.88	4.67	.51	-.01	.02
Pamlico	.79	5.43	.58	-.08	0
Pitt	.73	4.01	.43	-.15	.01
Wayne	.84	4.10	.44	-.05	.02
Wilson	.90	4.24	.46	0	.02
District	.85	5.20	.56	-.04	.02
South Coastal:					
Bladen	.90	4.52	.49	.01	.02
Brunswick	1.00	5.98	.63	.09	.04
Columbus	.85	4.65	.51	-.04	.01
Cumberland	.96	3.88	.42	.04	.04
Duplin	.88	5.30	.54	.01	0
Harnett	.84	2.61	.25	-.01	-.02
Hoke	.73	3.24	.33	-.10	-.04
New Hanover	.97	6.26	.65	.05	.05
Onslow	1.05	6.56	.67	.15	.02
Pender	.84	4.59	.46	-.04	.01
Robeson	.84	3.82	.41	-.04	0

See footnotes at end of table.

Continued--

Appendix table 6--Estimates of revenue risk-minimizing hedge ratios and their components for corn grown in selected North Carolina counties, 1961-83--Continued

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
South Coastal (continued):					
Sampson	0.96	5.05	0.55	0.06	0.03
Scotland	.84	3.10	.31	-.03	-.01
District	.91	4.90	.53	.01	.02
North Mountain:					
Yadkin	.82	4.33	.47	-.08	.02
District	.84	4.53	.49	-.09	.04
West Mountain:					
Rutherford	.76	4.11	.45	-.09	-.02
District	.78	6.22	.65	-.29	0
North Piedmont:					
Franklin	.56	2.13	.18	-.24	-.02
Vance	.64	3.07	.31	-.21	0
Warren	.68	3.09	.31	-.16	.02
District	.74	3.66	.38	.03	.02
Central Piedmont:					
Rowan	.97	3.64	.39	-.11	.07
Wake	.78	3.05	.31	-.10	.01
District	.81	3.87	.42	-.21	.03
South Piedmont:					
Anson	.67	2.35	.21	-.08	0
Cleveland	.83	3.19	.33	-.07	.04
Lincoln	.89	3.15	.32	-.07	.08
Richmond	.42*	1.64	.11	-.40	-.05
Stanly	.84	3.01	.30	-.09	.06
Union	.87	2.59	.24	-.14	.03
District	.76	2.95	.29	-.05	.03
State	.84	5.26	.57	-.05	.02
County average	.83	NA	.39	-.06	.02

NA = Not applicable.

*Significantly different from 1 at the 5-percent confidence level.

**Significantly different from zero at the 5-percent confidence level.

1/ The price risk-minimizing hedge ratio is 0.87 at Wilson. The standard error is 0.086, and the R^2 is 0.83.

Appendix table 7--Proportional risks in yield and revenue over the growing season and the effect of the natural hedge for corn and soybeans grown in selected States, 1961-83

State	Corn			Soybeans		
	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/	Yield risk 1/	Revenue risk 2/	Natural hedge effect 3/
Alabama	0.20	0.27	0.12	0.12	0.19	0.24
Arkansas	.20	.22	.43	.13	.16	.51
Georgia	.23	.30	.09	.21	.29	-.06
Illinois*	.13	.18	.47	.10	.10	.74
Indiana*	.13	.18	.46	.09	.14	.52
Iowa*	.12	.20	.28	.07	.15	.38
Kansas	.13	.20	.28	.22	.17	.66
Kentucky	.17	.24	.19	.13	.14	.61
Louisiana	.17	.23	.26	.11	.21	0
Michigan*	.09	.19	.31	.12	.17	.34
Minnesota*	.14	.20	.33	.13	.17	.46
Mississippi	.18	.23	.30	.14	.15	.56
Missouri	.21	.22	.45	.14	.12	.71
Nebraska*	.13	.20	.30	.15	.16	.54
North Carolina	.17	.27	-.01	.10	.17	.29
Ohio*	.10	.16	.49	.10	.16	.40
South Carolina	.20	.27	.16	.15	.19	.34
South Dakota*	.20	.23	.37	.17	.19	.43
Tennessee	.16	.22	.27	.12	.15	.52
United States	.09	.17	.40	.07	.12	.59
State average	.16	.21	.29	.13	.17	.43

*Soybean yield trend is statistically significant at the 5-percent confidence level. All States exhibit statistically significant trends in corn yields.

1/ Standard deviation of actual yield/expected yield.

2/ Standard deviation of actual revenue/expected revenue. Estimated standard deviations of actual price/expected price for Chicago corn and Chicago soybeans are 0.20 and 0.17, respectively.

3/ Proportional reduction in revenue variance due to negative correlation between price and yield.

Appendix table 8--Estimates of revenue risk-minimizing hedge ratios and their components for corn grown in selected States, 1961-83

State	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
Alabama	0.86	3.85	0.41	-0.11	0.01
Arkansas	.43*	1.98	.16	-.49**	-.05
Georgia	.95	3.87	.42	-.03	0
Illinois	.60*	4.36	.48	-.33**	-.04
Indiana	.59*	4.16	.45	-.33**	-.05
Iowa	.76	5.45	.59	-.18	-.04
Kansas	.79	5.62	.60	-.18	0
Kentucky	.78	3.93	.42	-.24	.05
Louisiana	.73	3.88	.42	-.21	-.03
Michigan	.76*	6.34	.66	-.16	-.06
Minnesota	.68	4.19	.45	-.26	-.04
Mississippi	.65	3.17	.32	-.29	-.04
Missouri	.49*	2.34	.21	-.47**	-.01
Nebraska	.70	4.45	.49	-.23	-.05
North Carolina	.97	4.86	.53	-.05	.05
Ohio	.62*	5.51	.59	-.27	-.08**
South Carolina	.83	3.71	.40	-.13	-.01
South Dakota	.46*	2.00	.16	-.43**	-.08
Tennessee	.73	4.01	.43	-.26	.02
United States	.70*	6.27	.65	-.24**	-.04
State average	.70	NA	.41	-.24	-.03

NA = Not applicable.
*Significantly different from 1 at the 5-percent confidence level.
**Significantly different from zero at the 5-percent confidence level.
1/ The price risk-minimizing hedge ratio is 0.97 (using Chicago prices). The standard error is 0.058, and the R^2 is 0.93.

Appendix table 9--Estimates of revenue risk-minimizing hedge ratios and their components for soybeans grown in selected Iowa counties, 1961-83

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
Northwest:					
Buena Vista	0.76	6.38	0.66	-0.21	0
Clay	.75	5.96	.63	-.17	-.05**
Emmet	.94	7.21	.71	0	-.02
Obrien	.77	4.74	.52	-.13	-.07**
Palo Alto	.88	8.58	.78	-.06	-.03
Pocahontas	.82	6.92	.70	-.12	-.03
District	.79	6.94	.70	-.14	-.04
North Central:					
Butler	.82*	9.85	.82	-.09	-.06**
Floyd	.73*	6.42	.66	-.18	-.06
Hancock	.85	10.25	.83	-.08	-.03**
Kossuth	.95	10.66	.84	.01	-.03**
Winnebago	.80	7.32	.72	-.13	-.04
Wright	.80*	12.02	.87	-.12	-.04**
District	.83*	11.57	.86	-.09	-.04**
Northeast:					
Allamakee	.78	6.46	.67	-.15	-.04
Bremer	.86	10.82	.85	-.07	-.03
Chickasaw	.74	5.76	.61	-.18	-.05
Delaware	.76*	8.44	.77	-.17	-.03
Fayette	.92	9.89	.82	-.02	-.02
Winneshiek	.75	5.18	.56	-.16	-.06
District	.82*	9.75	.82	-.11	-.03
West Central:					
Calhoun	.83	7.26	.72	-.10	-.04**
Crawford	.75*	7.06	.70	-.17	-.04**
Guthrie	.71*	6.14	.64	-.19	-.07**
Ida	.67*	5.63	.60	-.26**	-.03
Sac	.73*	7.09	.71	-.23**	-.01
Woodbury	.68*	4.67	.51	-.27	-.01
District	.73*	8.02	.75	-.19	-.05**
Central:					
Dallas	.79	6.75	.68	-.10	-.07**
Hamilton	.74*	6.55	.67	-.12	-.11**
Jasper	.69*	5.87	.62	-.17	-.11**
Polk	.67*	4.96	.54	-.17	-.12**
Story	.81	5.45	.59	-.01	-.15**
Webster	.79*	8.10	.76	-.12	-.06**
District	.81	8.28	.77	-.07	-.09**

See footnotes at end of table.

Continued--

Appendix table 9--Estimates of revenue risk-minimizing hedge ratios and their components for soybeans grown in selected Iowa counties, 1961-83--Continued

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/ Yield risk	Interaction risk
East Central:					
Benton	0.88	14.44	0.91	0.05	0.03**
Clinton	.58*	6.67	.68	-.33**	-.06
Iowa	.63*	5.96	.63	-.24**	-.09**
Johnson	.65*	8.01	.75	-.25**	-.07**
Jones	.67*	7.94	.75	-.25**	-.06**
Muscatine	.75*	8.96	.79	-.16	-.06**
District	.71*	10.50	.84	-.20**	-.06**
Southwest:					
Adair	.79*	7.71	.74	-.11	-.06**
Cass	.73*	9.35	.81	-.19**	-.04**
Fremont	.81	8.35	.77	-.11	-.04**
Montgomery	.77*	8.85	.79	-.16	-.04**
Pottawattamie	.72*	9.32	.81	-.21**	-.04**
Taylor	.60*	4.28	.47	-.29	-.08**
District	.74*	9.92	.82	-.18	-.05**
South Central:					
Appanoose	.51*	3.16	.32	-.36**	-.11**
Decatur	.53*	3.00	.30	-.35	-.09**
Madison	.69	4.33	.47	-.13	-.14**
Monroe	.53*	2.83	.28	-.31	-.13**
Union	.69	4.47	.49	-.17	-.10**
Wayne	.57*	3.55	.38	-.31	-.10**
District	.61*	4.13	.45	-.24	-.11**
Southeast:					
Davis	.55*	3.10	.31	-.31	-.11**
Henry	.64*	6.67	.68	-.27**	-.06**
Keokuk	.62*	5.35	.58	-.28**	-.07**
Louisa	.64*	6.37	.66	-.25**	-.07**
Van Buren	.66*	6.07	.64	-.22	-.09**
Washington	.57*	4.82	.53	-.29**	-.11**
District	.61*	6.09	.64	-.27	-.08**
State	.76*	10.07	.83	-.15**	-.06**
County average	.73	NA	.65	-.18	-.06

NA = Not applicable.
*Significantly different from 1 at the 5-percent confidence level.
**Significantly different from zero at the 5-percent confidence level.
1/ The price risk-minimizing hedge ratio is 0.96 at Des Moines. The standard error is 0.031, and the R^2 is 0.98.

Appendix table 10--Estimates of revenue risk-minimizing hedge ratios and their components for soybeans grown in selected Nebraska counties, 1961-83

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
North:					
Boyd	0.53	1.36	0.08	-0.61	0.04
District	.99	3.90	.42	-.10	.01
Northeast:					
Antelope	.75	3.23	.33	-.35	.01
Burt	.55*	2.97	.30	-.45**	-.07
Cuming	.66	3.19	.33	-.39**	-.03
Dixon	.59	2.49	.23	-.44	-.06
Madison	.55	2.43	.22	-.49**	-.04
Stanton	.54	2.43	.22	-.52**	-.02
Wayne	.64	2.51	.23	-.40	-.04
District	.61	2.92	.29	-.43**	-.04
Central:					
Buffalo	.99	9.11	.80	-.06	-.05**
Dawson	.87	4.16	.45	-.14	-.07
Hall	.79	7.00	.70	-.20**	-.09**
Sherman	.75	4.92	.54	-.31**	-.02
District	.88	8.52	.78	-.14	-.06**
East:					
Butler	.57	2.76	.27	-.50**	-.01
Colfax	.64	3.10	.31	-.44**	-.01
Douglas	.82	4.95	.54	-.26	-.01
Lancaster	.60	3.10	.31	-.46**	-.02
Nance	.83	4.09	.44	-.27	.02
Polk	.77	4.59	.50	-.28	-.04
Saunders	.65	3.13	.32	-.43**	0
Washington	.68*	4.39	.48	-.37**	-.04
District	.66	3.73	.40	-.39**	-.02
Southwest	.77	4.63	.51	-.29**	-.02
South:					
Adams	.62*	3.92	.42	-.36**	-.10**
Phelps	.95	7.52	.73	-.14	.01
District	.68*	6.00	.63	-.33**	-.07**

See footnotes at end of table.

Continued--

Appendix table 10--Estimates of revenue risk-minimizing hedge ratios and their components for soybeans grown in selected Nebraska counties, 1961-83--Continued

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/ Yield risk	Interaction risk
Southeast:					
Clay	0.68	3.49	0.37	-0.34	-0.06
Gage	.42*	1.94	.15	-.62**	-.05
Johnson	.51	2.11	.18	-.59**	.02
Nuckolls	.84	4.20	.46	-.22	-.02
Pawnee	.47*	2.04	.17	-.57**	-.04
Saline	.61	2.97	.30	-.45**	-.02
District	.56*	3.36	.35	-.48**	-.04
State	.63	3.60	.38	-.42**	-.03
County average	.67	NA	.37	-.38	-.03

NA = Not applicable.
*Significantly different from 1 at the 5-percent confidence level.
**Significantly different from zero at the 5-percent confidence level.
1/ The price risk-minimizing hedge ratio is 1.08 at Omaha. The standard error is 0.083, and the R^2 is 0.89.

Appendix table 11--Estimates of revenue risk-minimizing hedge ratios and their components for soybeans grown in selected North Carolina counties, 1961-83

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/ Yield risk	Component 1/ Interaction risk
North Coastal:					
Bertie	0.71	3.72	0.40	-0.23	-0.03
Camden	1.00	7.24	.71	-.02	.04**
Chowan	.77	5.27	.57	-.19	-.01
Currituck	.87	6.22	.65	-.13	.02
Edgecombe	.78	5.74	.61	-.16	-.02
Gates	.74	3.97	.43	-.19	-.05
Halifax	.70	3.26	.34	-.25	-.02
Hertford	.64	3.19	.33	-.29	-.04
Martin	.76	4.77	.52	-.18	-.03
Nash	.59	2.84	.28	-.29	-.09**
Northampton	.55*	3.08	.31	-.40**	-.02
Pasquotank	.85	7.75	.74	-.13	.01
Perquimans	.85	6.62	.68	-.11	-.02
Tyrell	1.15	6.59	.67	.17	0
Washington	.85	6.84	.69	-.12	0
District	.81	7.78	.74	-.15	-.02
Central Coastal:					
Beaufort	.85	7.24	.71	-.08	-.04**
Carteret	.77*	7.33	.72	-.17	-.03
Craven	.64*	4.15	.45	-.22	-.11**
Greene	.82	4.72	.51	-.09	-.06
Hyde	.90	6.99	.70	-.04	-.03**
Johnston	.71	3.35	.35	-.23	-.04
Jones	.77	5.51	.59	-.11	-.09**
Lenoir	.64*	4.59	.50	-.25	-.08**
Pamlico	.81	6.50	.67	-.10	-.06**
Pitt	.73	4.26	.46	-.17	-.07**
Wayne	.87	5.79	.61	-.11	0
Wilson	.82	3.70	.40	-.12	-.03
District	.77*	7.00	.70	-.15	-.06**
South Coastal:					
Bladen	.83	5.36	.58	-.07	-.07**
Brunswick	.89	6.66	.68	-.09	.01
Columbus	.87	6.39	.66	-.07	-.03
Cumberland	.84	4.95	.54	-.11	-.02
Duplin	.83	7.10	.71	-.09	-.06**
Harnett	.82	3.94	.43	-.10	-.05
Hoke	.75	3.80	.41	-.15	-.08**
New Hanover	.91	7.32	.72	-.01	-.05**
Onslow	.93	9.58	.81	-.01	-.04**
Pender	.85	6.30	.65	-.14	.01

See footnotes at end of table.

Continued--

Appendix table 11--Estimates of revenue risk-minimizing hedge ratios and their components for soybeans grown in selected North Carolina counties, 1961-83--Continued

District and county	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
South Coastal (continued):					
Robeson	0.81	4.23	0.46	-0.12	-0.05
Sampson	.88	6.41	.66	-.07	-.03
Scotland	.57	2.51	.23	-.34	-.06
District	.81	6.00	.63	-.12	-.04**
North Mountain:					
Yadkin	.81	3.86	.41	-.14	-.03
District	.78	4.10	.45	-.15	-.04
West Mountain:					
Rutherford	.63*	3.61	.38	-.29	-.05
District	.67*	4.78	.52	-.26	-.04
North Piedmont:					
Franklin	.49	1.97	.16	-.39	-.08
Vance	.56	2.30	.20	-.36	-.04
Warren	.59	2.60	.24	-.35	-.02
District	.65	3.42	.36	-.26	-.06
Central Piedmont:					
Rowan	.82	2.87	.28	-.11	-.04
Wake	.79	3.62	.38	-.12	-.06**
District	.79	3.94	.42	-.14	-.04
South Piedmont:					
Anson	.81	3.49	.37	-.13	-.04
Cleveland	.99	4.71	.51	.10	-.08**
Lincoln	.98	4.53	.49	.07	-.07
Richmond	.72	3.00	.30	-.23	-.02
Stanly	.92	3.77	.40	0	-.05
Union	.85	3.44	.36	-.09	-.04
District	.87	3.98	.43	-.05	-.05
State	.77*	6.84	.69	-.15	-.05**
County average	.79	NA	.50	-.14	-.04

NA = Not applicable.
*Significantly different from 1 at the 5-percent confidence level.
**Significantly different from zero at the 5-percent confidence level.
1/ The price risk-minimizing hedge ratio is 0.98 at Raleigh. The standard error is 0.039, and the R^2 is 0.97.

Appendix table 12--Estimates of revenue risk-minimizing hedge ratios and their components for soybeans grown in selected States, 1961-83

State	Risk-minimizing hedge ratio	T-value	R^2	Component 1/	
				Yield risk	Interaction risk
Alabama	0.75	4.78	0.52	-0.20**	-0.01
Arkansas	.56*	3.81	.41	-.37**	-.03
Georgia	1.00	3.62	.38	-.05	.08
Illinois	.44*	5.41	.58	-.44**	-.07**
Indiana	.62*	6.05	.64	-.29**	-.06
Iowa	.74*	8.29	.77	-.17	-.06**
Kansas	.24*	1.21	.07	-.76**	.06
Kentucky	.51*	3.99	.43	-.44**	0
Louisiana	.96	6.59	.67	-.04	.03
Michigan	.68*	4.56	.50	-.25	-.03
Minnesota	.57*	3.67	.39	-.34**	-.05
Mississippi	.51*	3.50	.37	-.39**	-.05**
Missouri	.44*	3.82	.41	-.51**	.01
Nebraska	.47	2.81	.27	-.45**	-.03
North Carolina	.75	5.87	.62	-.17	-.05**
Ohio	.70*	5.69	.61	-.23	-.04
South Carolina	.62	3.27	.34	-.30	-.03
South Dakota	.52*	2.66	.25	-.39**	-.04
Tennessee	.57*	4.45	.49	-.35**	-.03
United States	.61*	10.10	.83	-.30**	-.04
State average	.61	NA	.46	-.32	-.02

NA = Not applicable.
*Significantly different from 1 at the 5-percent confidence level.
**Significantly different from zero at the 5-percent confidence level.
1/ The price risk-minimizing hedge ratio is 0.97 at Chicago. The standard error is 0.032, and the R^2 is 0.98.

Appendix table 13--Hedging effectiveness of arbitrary hedges for representative counties and States

Crop and location	Risk-minimizing hedge ratio	R^2	Effectiveness of arbitrary hedge 1/									
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Corn grown in--												
Polk County, IA	0.73	0.61	0.15	0.29	0.39	0.48	0.55	0.59	0.61	0.60	0.58	0.53
Logan County, NE	.68	.42	.11	.21	.29	.35	.39	.42	.42	.41	.38	.33
Wayne County, NC	.84	.44	.10	.19	.26	.32	.37	.41	.43	.44	.44	.43
Minnesota	.68	.45	.12	.23	.31	.38	.42	.45	.45	.44	.41	.36
U.S. total	.70	.65	.17	.32	.44	.53	.60	.64	.65	.64	.60	.53
Soybeans grown in--												
Clay County, IA	.75	.63	.16	.31	.41	.50	.57	.60	.63	.63	.61	.56
Cuming County, NE	.66	.33	.11	.18	.24	.29	.31	.33	.33	.32	.29	.24
Martin County, NC	.76	.52	.14	.25	.34	.40	.43	.50	.52	.52	.40	.47
Tennessee	.57	.49	.17	.29	.39	.46	.49	.49	.45	.39	.21	.19
U.S. total	.61	.83	.26	.47	.63	.74	.83	.83	.81	.74	.63	.41

1/ Proportional reduction in revenue variance.

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